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Journal of the American Heart Association

EDITORIAL

New ECG Criteria for Acute Myocardial Infarction in Patients With Left Bundle Branch Block

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Sensitive and specific criteria for the detection of acute myocardial infarction (AMI) in patients with left bundle branch block (LBBB) have eluded electrocardiographers for many years. The article by Di Marco et al in this issue of the *Journal of the American Heart Association* (*JAHA*)[1] suggests that enhanced criteria are a possibility. In 1996, Sgarbossa et al introduced new criteria for the diagnosis of AMI in LBBB purely on the basis of ST changes, with a sensitivity of 36%, a specificity of 96%, and a positive predictive value of 88%.[2] At the time, they represented a new approach, but they were enhanced later by Smith et al, whose modified Sgarbossa criteria[3] had a sensitivity of 91% and a specificity of 90%, although the study group was somewhat small.[3] A follow-up case-control study that assessed the same criteria produced results of 80% sensitivity and 99% specificity in 45 patients with an acute coronary occlusion and 249 controls.[4] The modification of Smith et al[3] was to replace one Sgarbossa criterion (STj ≥0.5 mV discordant with QRS) with a new criterion, namely |STj/Samp| ≥0.25 with STj ≥0.1 mV in the same lead.

See Article by Di Marco et al.

In the article by Di Marco et al, the sensitivity and specificity in the test group of 107 patients were 93% and 94%, respectively.[1] This compares with 33% and 99% for the original Sgarbossa[2] criteria and 68% and 94% for the modified Sgarbossa criteria,[3,4] all based on the same test population of patients. Thus, the new approach represents a remarkable improvement in sensitivity, in particular compared with earlier approaches.

DEFINITION OF LBBB

The authors chose a relatively conventional definition of LBBB with the QRS duration >0.12 seconds, QS or rS complex in V1, and an R wave peak time >60 ms in lead I, V5, or V6 along with the absence of a Q wave in these leads.[1] There was no requirement for notching or slurring of the R wave in I, V5, and V6 as in the long-standing World Health Organization definition of LBBB.[5] In 2009, an American Heart Association/American College of Cardiology Foundation/Heart Rhythm Society recommendations article[6] produced a broader definition of LBBB, which stated that ST-T waves are usually oppositely directed to the QRS complex, and positive T waves in the presence of an upright QRS complex may be normal. Subsequently, Strauss et al introduced a definition of strict LBBB with a QRS duration ≥130 ms in women and ≥140 ms in men.[7] A QS or rS complex in V1 and V2, as well as notching or QRS slurring in mid-QRS in ≥2 contiguous leads, completed their definition. They argued that many ECGs reported as showing LBBB had a wide QRS because of a combination of left ventricular hypertrophy and left anterior fascicular block and not LBBB. Their research was aimed at assessing the likelihood of success of cardiac resynchronization

Key Words: Editorials ■ ECG ■ ECG criteria ■ left bundle branch block ■ myocardial infarction

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therapy, and hence they were using a strict definition of LBBB. Whether the definition of LBBB by Strauss et al[7] would have altered results in the current study[1] is a question that cannot be answered here.

Figure 1 shows an example of LBBB in a 76-year-old woman. The reader is invited to review this ECG, and in the absence of any clinical details, consider the interpretation. Further discussion of this example will follow.

METHODS

In the study of Di Marco et al,[1] all ECGs were interpreted visually by 2 cardiologists and there was an exceptionally high agreement between them (κ coefficient=0.98). Measurements >0.1 mV (1 mm) were made to the nearest 0.05 mV. This does raise the question that if ST amplitude, for example, happened to be bordering on 0.1 mV (eg, 0.095 mV), then it could have possibly influenced a cardiologist aware of a threshold of 0.1 mV. Of course, such a situation could affect both sensitivity and specificity, but it might mean that if automated methods were used for ECG interpretation of a new test set at some future point, the results of automated versus manual interpretation could differ.

The biggest difference between the new criteria and the original Sgarbossa criteria is that the new approach is not a point scoring system. The new criteria of Di Marco et al[1] have 2 major differences compared with previous criteria:

1. Although the Sgarbossa criteria used ST depression ≥0.1 mV as a criterion for AMI only in leads V1 to V3 with a dominant Q or S wave, the new approach extends this criterion to any lead (ie, where the ST depression and the QRS complex are "concordant");
2. A completely new criterion, applicable in any lead, of ST deviation ≥0.1 mV, which is "discordant" with the QRS complex where the dominant QRS wave ≤0.6 mV (ie, the STj amplitude is oppositely directed to the dominant QRS deflection). Note that this is not peak to peak QRS amplitude.

These 2 new criteria, together with an existing Sgarbossa criterion (namely, ST elevation ≥0.1 mV), which is concordant with the QRS complex, constitute the new so-called Barcelona algorithm, which is positive if any 1 of the 3 above mentioned criteria is met.

VOLTAGES IN LBBB

The interesting new criterion is the use of a low-voltage QRS complex together with ST deviation. It therefore is of some interest to consider the vectorcardiogram of LBBB, as shown in Figure 2.

The classic LBBB pattern has a relatively narrow QRS loop and slow inscription signified by the close spacing of the dots that form the loop. In general terms, the T-wave loop is oppositely directed from the QRS loop. Leads that are directed essentially parallel to the QRS loop, particularly in the transverse plane (eg, a precordial lead, such as lead V1 or V2), will have a high QRS voltage. Leads that are more directed at right angles to the VCG loop, such as V4 and V5 in this example, will have lower voltages because the

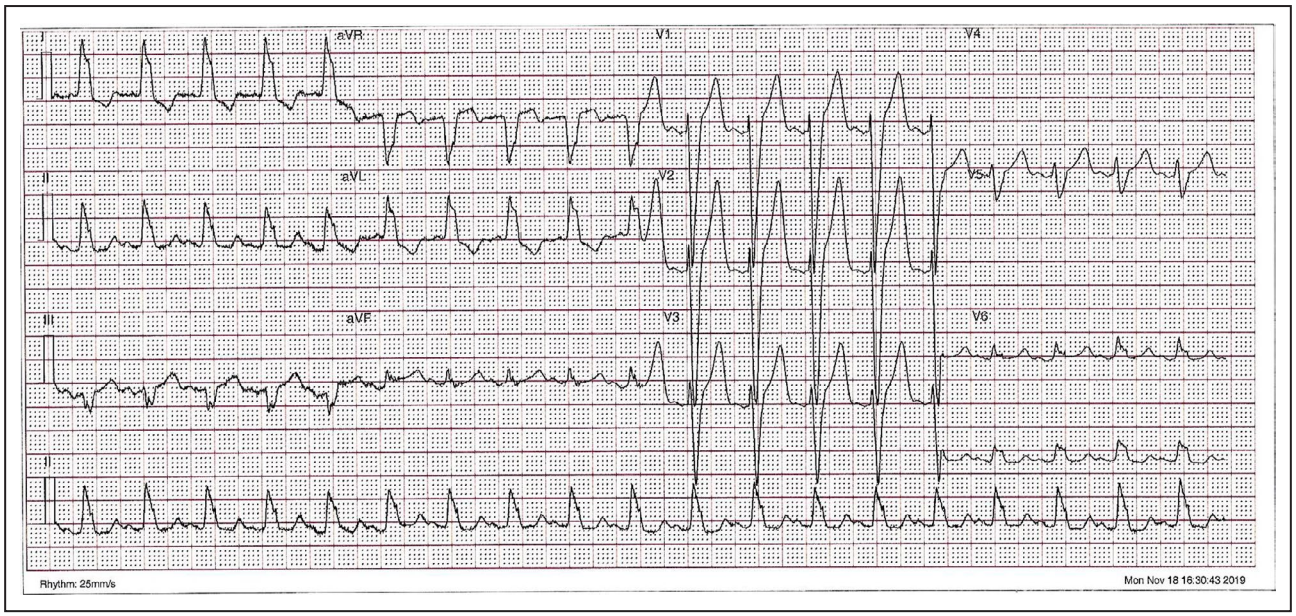

Figure 1. A 12-lead ECG showing left bundle branch block with a QRS duration of 136 ms, recorded from a 76-year-old woman.
Does it show evidence of an acute myocardial infarction?

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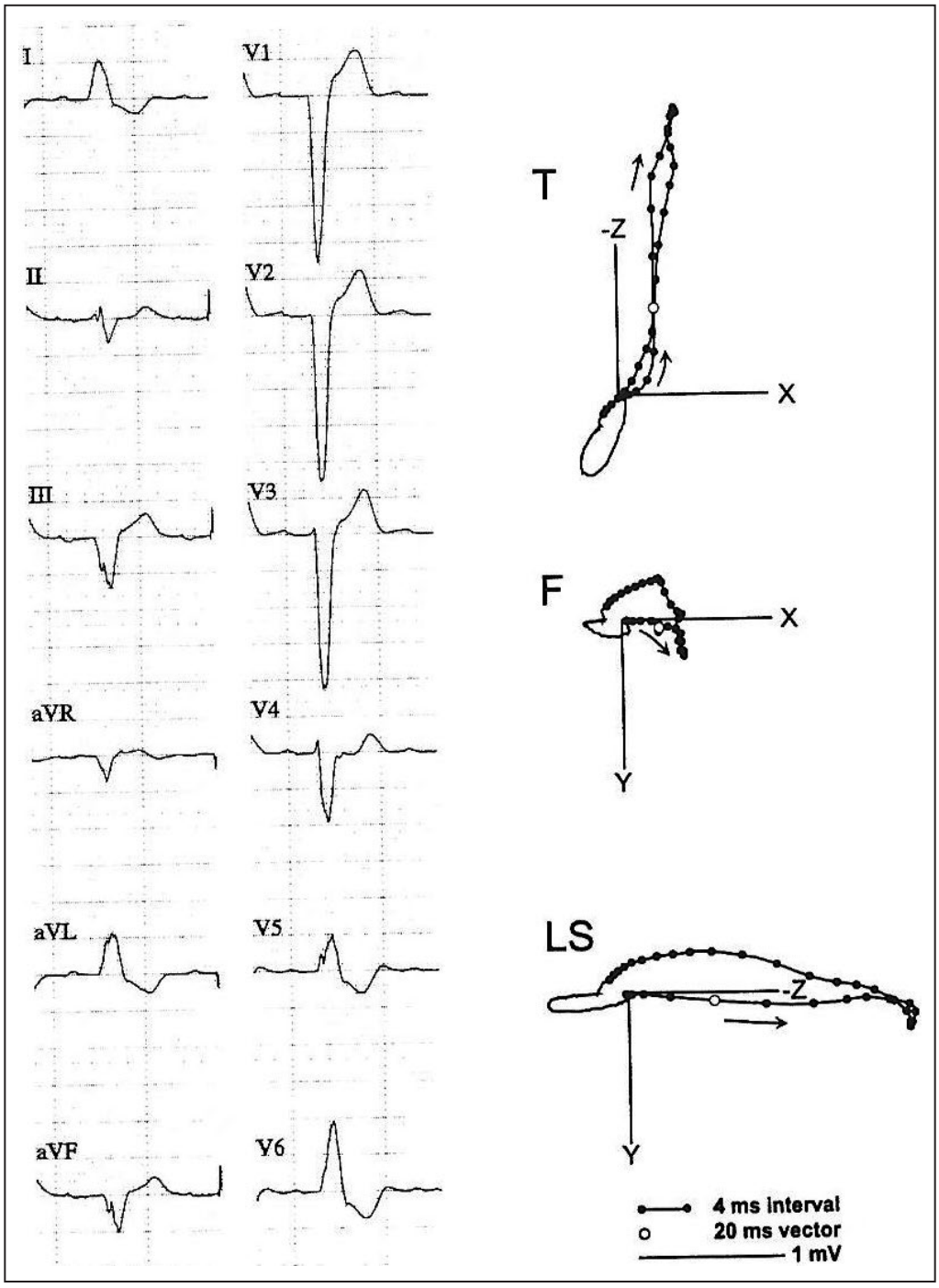

Figure 2. A 12-lead ECG and derived vectorcardiogram (VCG) demonstrating left bundle branch block.
The 3 planes of the VCG are transverse (T), frontal (T), and left sagittal (LS). The 3 orthogonal leads X, Y, and –Z, from which the VCG is constructed, are directed similarly to V6, aVF, and V2, respectively.

component of the electrical activity in these leads is much less than in those leads directed similarly to the main QRS loop. It can be seen in Figure 2 that the voltage in V5 is less than one quarter of the voltage in V1. Thus, it can be expected that there will be a large variation in the amplitude of the QRS complex in ECGs with LBBB. This can also be seen in Figure 1 of the article by Di Marco et al.[1] There is therefore a small probability that evolving ST depression in the left lateral leads from V4, for example, toward V6 in an LBBB recorded from a patient without an AMI could therefore be associated with a low-voltage QRS complex.

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This might account for the slightly reduced specificity of 94% in the new Barcelona criteria compared with 99% in the Sgarbossa criteria, but of course sensitivity is exceptionally high in the former at 93% compared with 33% in the latter.

ST depression in LBBB with a QRS amplitude ≤0.6 mV will undoubtedly occur in subjects without an AMI, possibly meeting the new Barcelona criterion of discordant ST deviation ≥0.1 mV. Of course, it is unrealistic to expect all criteria to be 100% specific! Sperry et al[8] suggested that LBBB does not deter assessment of low-QRS voltage in patients with cardiac amyloidosis, for example. Other well-known causes of low voltage, such as chronic obstructive pulmonary disease, can occasionally occur in a patient with an LBBB.[9] So, it would be unreasonable to expect any ECG criterion to be perfectly specific, but the Barcelona criteria do manage to marry a high specificity to a high sensitivity.

SENSITIVITY AND SPECIFICITY

All the measurements in this study were made manually. In their supplementary data, the authors give an example where approximation of a measurement could lead to a different interpretation of one of the modified Sgarbossa criteria, depending on whether approximation of ST depression was 0.15 or 0.2 mV. This is because the ratio |STj/Samp| was involved. In the new Barcelona criteria, no ratios are involved. However, a similar situation must arise where the amplitude of an R or S wave could be 0.62 mV when measured by computer but a manual estimate measuring to the nearest 0.05 mV could be 0.6 mV. In the latter case, this wave would meet one of the Barcelona thresholds, being ≤0.6 mV, whereas the automated measurement would not. Of course, it could be argued development of the criteria is based on manual measurements and therefore application would also apply to manual measurements but clearly there is scope for variation here, as in any manual versus automated ECG measurement.

The authors performed a separate assessment of specificity on 214 hospital patients without any evidence of an AMI and who had not undergone cardiac catheterization. Specificity of the Barcelona criteria remained high at 90%, although this was the lowest specificity of all criteria.

Perhaps one of the most surprising aspects of the new criteria is the fact that discordant ST depression in V6, for example, can be regarded as a positive indicator of myocardial infarction if the R-wave amplitude is ≤0.6 mV. This criterion had a surprisingly high specificity of 94%, even when assessed together with concordant ST elevation.

For this reason, the author made a rapid review of 50 cases of LBBB selected at random from a local database of several hundred thousand ECGs recorded mainly in a hospital setting. Time did not permit analysis of a larger sample. However, it was found that 94% of examples had a maximum R or S wave ≤0.6 mV in ≥1 lead. There is therefore scope for checking the new Barcelona criterion of significant discordant ST deviation.

It should also be noted that in Fig. 2, the R amplitude in V5 is approximately 0.5 mV and the STj depression exceeds 0.1 mV and so the Barcelona algorithm is positive.

ECG EXAMPLE

With the above discussion in mind, the reader is encouraged to review again the ECG of Figure 1. Measurements quoted below were derived from automated analysis of the ECG using software from the author's laboratory.[10]

The leads of most interest are V2 and V4. The ST amplitude in V2 is 0.542 mV, meeting one of the Sgarbossa criteria, but this does not produce a score sufficient to report AMI. The S-wave amplitude in V2 is 2.841 mV and so in this lead |STj/Samp|=0.19 and so the modified Sgarbossa criteria[3] are not met. This criterion was not met in any other lead. The new Barcelona criterion of discordant ST deviation ≥0.1 mV is met in V4, where ST amplitude is 0.105 mV and the dominant S wave is 0.482 mV and hence ≤0.6 mV. In summary, this ECG should be reported as showing AMI according to the new Barcelona criteria.

CLINICAL APPLICABILITY

Di Marco et al[1] point out that, in their cohort of patients referred for primary percutaneous coronary intervention, 63% unnecessarily underwent cardiac catheterization, no doubt in keeping with recommended guidelines, although the Sgarbossa criteria, with a specificity of 96%, were available, having been established in 1996. As the authors point out, the current European Society of Cardiology guidelines[11] advise that in a patient with a clinical suspicion of ongoing ischemic symptoms, an ECG showing LBBB should be regarded as an ST-segment–elevation myocardial infarction equivalent, even if there was a previous ECG showing LBBB. These guidelines also emphasized that the presence of a (presumed) new LBBB does not predict a myocardial infarction. Nonetheless, if the new criteria can be externally validated, they could on occasion be a valuable aid in decision making.

FURTHER STUDIES

The high sensitivity and specificity of the new Barcelona algorithm require to be assessed in an

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independent population, either manually or with automated techniques. It sometimes happens that criteria developed in one center do not perform so well when evaluated in another center. On the other hand, it could be argued that the established Sgarbossa criteria performed similarly in the Barcelona validation sample as in the original study.[2] Nevertheless, few ECG criteria have been shown through the years to be the order of 93% to 94% sensitive and specific and only time will tell whether the outstanding performance of the criteria set out in the article of Di Marco et al[1] will stand the test of independent assessment.

ARTICLE INFORMATION

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Disclosures

None.

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